

Spring 2006
Industry Study

Final Report
Shipbuilding Industry



The Industrial College of the Armed Forces
National Defense University
Fort McNair, Washington, D.C. 20319-5062

The views expressed in this report are those of the authors and do not reflect the official policy or Position of the Department of Defense or the U.S. Government.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE Spring 2006 Industry Study Shipbuilding Industry				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Industrial College of the Armed Forces,National Defense University,Fort McNair,Washington,DC,20319-5062				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 27	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

SHIPBUILDING 2006

ABSTRACT: Because the United States depends on the maritime domain for economic prosperity and national security, the shipbuilding industry is of strategic importance. Unfortunately, this industry is currently in crisis. Although the industry meets both commercial and defense requirements, it faces affordability and workforce challenges. The defense sector, though producing the most advanced ships in the world, does so at exorbitant prices, limiting the number that the U.S. Navy can afford. Based on visits to twenty-four U.S. and Australian shipyards, the U.S. government should provide targeted support to the commercial sector and consolidate defense construction into two facilities.

LTC Deborah Broughton, U.S. Army

Mr. Thomas Chaleki, U.S. Coast Guard

CDR Mike Christian, U.S. Coast Guard

CDR Gary Edwards, U.S. Navy

LTC Casey Flagg, U.S. Army

Mr. David Grove, Military Sealift Command

LTC John Hess, U.S. Army

Ms. Dina Hirsch, Dept of Army

Lt Col David Ptak, U.S. Air Force

CDR John Sager, U.S. Navy

CDR Mark Weber, U.S. Navy

LTC Kenston Yi, U.S. Army

Dr. Mark Montroll, Faculty

Dr. Michael Farbman, U.S. Agency for International Development, Faculty

CAPT David B. Hill, U.S. Coast Guard, Faculty

ICAF

The views expressed in this report are those of the authors and do not reflect the official policy or Position of the Department of Defense or the U.S. Government.

PLACES VISITED

Domestic

U.S. Coast Guard Shipyard, Curtis Bay, MD
 Aker Philadelphia Shipyard, Philadelphia, PA
 Carnival Corporation & Carnival Cruise Lines, Miami, FL
 Electric Boat, Quonset Point, RI
 Portsmouth Naval Shipyard, Portsmouth, NH
 Bath Iron Works, Bath, ME
 Marinette Marine-Manitowoc Marine Group, Marinette, WI
 Northrop Grumman Ship Systems-Avondale Operations, Avondale, LA
 Waterman Steamship Corporation, New Orleans, LA
 Textron Systems-Marine & Land Operations, New Orleans, LA
 Bollinger Shipyard, Lockport, LA
 VT Halter Marine-Pascagoula Operations, Pascagoula, MS
 Northrop Grumman Ship Systems-Ingalls Operations, Pascagoula, MS
 Austal USA, Mobile, AL
 Northrop Grumman Ship Systems-Newport News Shipbuilding, Newport News, VA
 SEAmagine Hydrospace Corporation, Claremont, CA
 National Steel and Shipbuilding Company (NASSCO), San Diego, CA

International

Tenix, Henderson, Western Australia
 HMAS Stirling Naval Base, Garden Island, Australia
 ANZAC Alliance, Rockingham, Australia
 Austal, Henderson, Western Australia
 Nautronix, Freemantle, Western Australia
 AWD Systems Centre, Adelaide, Australia
 Australia Submarine Corporation, Adelaide, Australia
 Tenix Shipyard, Williamstown, Australia
 INCAT, Hobart, Australia
 Lifesaving Systems, Hobart, Australia
 U.S. Embassy, Canberra, Australia
 DMO, Canberra, Australia
 Garden Island Dockyard, Sydney, Australia
 FFG Upgrade Project, Sydney, Australia

Introduction

*The safety and economic security of the United States depend upon the secure use of the world's oceans.
-The National Strategy for Maritime Security*

The United States is a maritime nation, with 95,000 miles of coastline, a 3.4 million square mile exclusive economic zone, and over 350 official ports of entry (USCG Maritime Strategy for Homeland Security, 2002, p. 7). In addition, 95% of U.S. trade travels by sea. Thus, the economy and the security of the nation depend on the maritime domain. Furthermore, as a global leader, the U.S. must be able to deploy forces globally to achieve national objectives. Therefore, the U.S. needs commercial and military ships, and shipbuilding is a vital, strategic industry.

Despite its importance, the U.S. shipbuilding industry is a mere shadow of its former state, and some experts believe that the industry is in crisis. Southeast Asia now completes the majority of new commercial ship construction; as a result, the U.S. shipbuilding industry has significantly consolidated. Only a few yards engage in commercial production, and six yards owned by two companies (Northrop Grumman and General Dynamics) complete most large naval shipbuilding. Although U.S. naval shipbuilding yards currently meet national security needs, the prices of naval vessels are high and increasing to the point that the U.S. Navy may not be able to afford the systems needed to meet mission requirements. In addition, there are concerns about the industry skilled labor and engineering workforce.

This shipbuilding industry study assesses the health of the industry and its ability to meet national security requirements. It defines the industry, reviews the current industry conditions, examines challenges facing it, explores its outlook and capability to meet future commercial and national security requirements, reviews possible government policy options, has two essays on relevant topics, and concludes with a recommendation to address the noted challenges.

To support this research, in addition to reviewing literature, members of the shipbuilding industry study visited fifteen U.S. and nine Australian shipyards, two commercial customers, and a systems supplier, attended a Navy League symposium, and received briefs from an industry trade representative and U.S. and Australian government officials. During visits, members met with corporate executives and managers, yard supervisors, government representatives, and union leaders. The members also met with representatives of the Royal Australian Navy and U.S. Navy - the primary customers of the Australian and large U.S. shipyards, respectively.

Shipbuilding Industry Defined

The shipbuilding industry includes firms that operate shipyards, or fixed facilities with dry docks and fabrication equipment capable of building ships. These establishments manufacture and repair cargo, container, passenger, sailing, and naval ships, ferry, fishing, and patrol boats, and barges. The two main segments are commercial and defense. Industry revenues are 70% from defense ship construction, 10% from defense repair, and 20% from commercial construction/repair (IbisWorld, 2006, pp. 3, 10). During visits, the team noted that most U.S. yards produce either commercial or defense vessels, but a few still work in both segments.

A “five forces” analysis adds insight into the U.S. shipbuilding industry (Porter, 1980):
1. Industry rivalry is high due to (a) slow market growth (the industry is in the declining lifecycle phase after decades of declining demand), (b) large exit barriers (due to expensive, specialized assets), (c) high concentration (especially in the U.S. defense sector in which two corporations now account for nearly all revenue following a period of consolidation), and (d) overcapacity

(exacerbated by politics and procurement preferences). The U.S. government (USG) uses anti-trust regulations to influence competition and concentration and prevented General Dynamics from purchasing Newport News Shipyard, but allowed Northrop Grumman to do so.

2. Buyer power is strong, especially in the defense segment. One buyer, the U.S. Navy (USN), accounts for nearly all sales and controls the demand curve, so there is nearly a bilateral monopoly (or monopsony). Ships also represent a significant portion of this buyer's budget. As a sign of buyer power and increasing buyer price elasticity of demand, Congress demanded a ceiling on the USN littoral combat ship price. Price elasticity is also high in the tourism and luxury yacht markets. This affects demand and makes it difficult to earn economic profits.

3. Supplier power is also strong because of low ship production volumes in both the commercial and defense segments. USN procurement instability and unpredictability make it difficult for defense firms to buy large volumes in order to increase power over suppliers and reduce costs.

4. Threat of substitutes has mixed effects on firms in the industry. The industry faces competition from alternate forms of transportation, such as rail and truck, and the tourism segment faces competition from other leisure activities. In addition, U.S. defense shipbuilders face contestability from foreign firms establishing U.S. subsidiaries, like Austal USA. However, once a firm supplies vessels to the USN, there are large switching costs due to investments in training, shore-side infrastructure, and spare parts, and this decreases the threat of substitutes.

5. Barriers to entry are extensive and include significant fixed costs for specialized assets, overcapacity, and significant cost advantages achieved through learning by doing. "Patents and proprietary knowledge serve to restrict entry" (QuickMBA), and existing firms possess these. Furthermore, in the defense sector, existing firms have long-established relations with the only customer, the U.S. Navy. "Stringent safety and regulations are entry barriers that have increased the costs of production" (IbisWorld, 2006, p. 9). Thus, although regulations decrease negative externalities, such as pollution, compliance increases costs, shifts the industry supply curve inward, and increases prices. U. S. domestic market protection through the Jones Act creates a further barrier to entry and decreases competition. This act requires that ships transporting goods between any two U.S. ports be U.S. built and crewed. This also shifts the supply curve inward and increases prices. There are also factors that may reduce entry barriers. The National Shipbuilding and Shipyard Conversion Act (1993) established financing for ship construction and yard modernization (IbisWorld, 2006, p. 14), and the Title XI loan guarantee program provides credit guarantees to enable vessel and yard owners to obtain financing at lower rates. These interventions reduce costs, encourage investment, and shift the supply curve outward.

In summary, rivalry among existing firms, strong buyer and supplier power, high exit barriers, and overcapacity make it challenging for firms in the industry to earn economic profits.

Current Condition

This section briefly reviews the condition of the international shipbuilding industry and then the U.S. industry commercial sector, defense sector, productivity, and financial information.

International

Global commercial shipbuilding production increased from a low in the 1980s to a peak in 2002 and 2003. However, new ship prices declined during the past five years due to overcapacity, improved productivity, and lower demand (the price of building a ship in 2002 was 19% lower than in 1997) (Rand, 2005, p. 67). "The leading commercial shipbuilding nations [in terms of gross tons in 2001 were] South Korea (43 % of the market), Japan (26 %), China (7 %),

and Germany, Italy and Poland (each with 3 %)” (U.S. Department of Commerce, 2001, p. 9). Japan and South Korea dominate the global market for low and moderate complexity cargo and tanker ships, and the Europeans dominate the market for more complex ships, such as cruise liners and liquefied natural gas carriers. The migration of the shipbuilding industry overseas is largely due to supportive national industrial policies (subsidies) in other countries. The governments of Japan, Korea, and Germany consider a robust shipbuilding industry to be integral to their economies. China, by heavily investing in its shipbuilding industry, increased its share of the world market from essentially 0% to achieve 18% today. Industry experts expect China to have 25% by 2010 (American Shipbuilding Association, 2006).

United States

The U.S. shipbuilding industry consists mainly of private firms competing in the free market, but also receiving government support/subsidies. This support consists of low-rate financing for customers, government reimbursement for cost-saving capital improvements, use of government real estate, and local and state grants and loans for training programs and infrastructure.

Commercial sector. The U.S. commercial shipbuilding industry was once competitive in the world market. Today, however, there are only three first-tier yards performing major commercial construction. This sector is no longer internationally competitive and does not export any vessels. Furthermore, it depends on domestic market protection through the Jones Act for survival. It also benefits from Title XI low-rate financing.

Defense sector. Defense shipbuilding production has been in decline since the high levels during the Reagan era, when the U.S. Navy expanded to a 600-ship fleet. Following the fall of the former Soviet Union, the U.S. reduced defense budgets, decreasing the number of ships the Navy could procure. The Navy’s annual budget went from about \$140 billion in FY84 to under \$100 billion in the mid 1990’s, at which point it started a slow increase to a level of about \$114 billion. As a result, in the early 1990’s, the Navy fleet fell to 400 ships, and the 1997 Quadrennial Defense Review (QDR) called for only 304 ships. At 280 ships today, the U.S. Navy has the smallest number of ships since World War II (O’Rourke, 2006a). Because of the budget and fleet reductions, the U.S. defense sector has consolidated and reduced the number of yards since the mid 1990s. Today, six yards owned by two companies are the primary suppliers of vessels to the U.S. Navy and Coast Guard.

Productivity. First Marine International (FMI) conducted the most recent commercial benchmarking study, published in August 2005 (FMI, 2005). It benchmarks six major U.S. shipyards against seven large international shipyards. As shown in Table 1, U.S. shipyards improved their overall score by 0.5 between the 1999/2000 and 2004 studies and closed the gap with international yards to only 0.2 in 2004. According to the study, the 0.1 annual improvement by U.S. yards compares favorably with the improvement by the international shipbuilders. From this study, it appears that U.S. shipyards invested in capital improvements (plant and equipment) and adopted processes that closed the productivity gap with international shipbuilders. During visits to the U.S. shipyards, we found that all of them have invested in capital improvements and have plans to continue doing so. Furthermore, the big six yards owned by parent corporations receive corporate financing for capital investments. We also noted that many of the yards are actively working to improve processes and have instituted Lean Six Sigma programs. Despite these gains, a company representative familiar with the techniques employed by U.S. and European shipyards advised us that the U.S. shipbuilding industry is currently about fifteen years behind in implementing changes that would enhance productivity.

Financial Information. According to an industry report, FY2005 industry revenues were

approximately \$13.9 billion, and net profit margins for individual firms ranged from 1.1% to 6.7% (IbisWorld, 2006, pp. 5, 25-31). Personnel at the visited Northrop Grumman and General Dynamics yards would not provide financial information for their shipyards, and company reports do not provide separate financial information for the marine units. However, managers advised us that the shipbuilding units of these organizations earned the lowest profit margins (one reported only 2 to 3 %) of any unit in their companies in 2005. Furthermore, these units are not meeting corporate profit expectations.

Table 1. U.S. and International Industry Best Practice Rating by Group and Overall (FMI, 2005).

Group	U.S. yards avg rating 1999/2000	U.S. yards avg rating 2004	International yards avg rating 2004
Steelwork production	2.9	3.3	3.7
Outfit manufacturing and storage	3.3	3.6	3.6
Pre-erection activities	3.1	3.4	3.8
Ship construction and outfitting	3.0	3.5	3.7
Yard layout and environment	2.6	3.2	3.4
Design, engineering and production engineering	3.4	3.6	3.8
Organization and operating systems	3.5	3.9	4.0
Overall industry rating	3.1	3.6	3.8

Challenges

There are many challenges facing the U.S. shipbuilding industry; two of the major ones are affordability and workforce issues.

Affordability

Although the U.S. shipbuilding industry designs and builds high quality commercial and sophisticated military vessels, the industry cannot compete internationally due to higher costs and prices. On the commercial side, based on information provided during visits, vessels produced in the U.S. are three times the price of comparable vessels produced in South Korea. Thus, only the Jones Act prevents the outsourcing of all U.S. commercial construction. Personnel at the U.S. yards visited that engage in commercial construction stated that they would lose all commercial work without the Jones Act. As learned during overseas visits, Australia once had a healthy commercial shipbuilding industry, but now does no commercial shipbuilding (even less than the U.S.) because it does not have market protection similar to the Jones Act. The cost of military ships in the U.S. is also high and is rising to a level that even the Department of Defense (DoD) may be unable to support. High price creates a cycle in which the USN orders fewer ships, spreading high overhead and fixed costs over fewer units and further increasing prices.

Although the lack of competitiveness is partly due to the policies of other countries (which U.S. firms do not control), it is also due to excess capacity, inefficiency, U.S. Navy funding and requirements instability, technology insertion into military vessels, and political interventions.

Excess Capacity. Annual shipyard production capacities for first-tier yards remain considerably higher than current Navy ship procurement planning (even the most optimistic) anticipates. For example, if Congress authorizes construction of CVN-21 (to replace the USS Enterprise), Newport News Shipyard would still have residual capacity to construct up to four SSN submarines (SSN construction is now only one per year). In fact, this one yard has sufficient capacity to handle all current naval construction. Ingalls can construct up to eight DDXs (destroyers) simultaneously, while retaining enough residual capacity to build a major amphibious ship. However, DDX construction levels will likely remain at one or two per year

through FY 2011, leaving considerable capacity (O'Rourke, 2006b, p. 36). On the commercial side, one representative said that his yard's goal is to produce three vessels per year, but it is only producing 1.5 per year now. This excess capacity was obvious in nearly every U.S. yard visited, with expensive capital equipment and infrastructure sitting idle in most yards.

Inefficiency. One of the most significant sources of inefficiency is learning curve efficiency, or learning by doing. In fact, yard supervisors advised us that throughput directly affects efficiency. As an example, DDG 96 took one million fewer labor hours (approximately ten percent of the total labor hours) to produce than DDG 92. This is important because labor accounts for 41% of ship production costs. Based on comments made during visits, foreign yards have a significant advantage in this area. A South Korean yard produces fifty to sixty commercial vessels a year. A U.S. commercial yard produces only one or two, which is not sufficient for workers to reach efficiency, let alone reduce costs through experience. One yard brought people from Europe to the U.S. and compared the performance of welders from the two locations. Due to less experience, the U.S. welders took about three times as long to complete the same work.

On the military side, each yard now produces at most a few vessels each year. The team visited a yard that produced a destroyer every 17 days during World War II and twelve vessels per year in the 1980s. Today, it produces only one vessel every eight months. Despite capacity under utilization, more than one yard often produces vessels of the same class. Thus, each yard produces fewer vessels and does not obtain potential learning curve efficiencies, increasing costs. As an example, an estimate for the premium to produce Virginia class submarines in two yards rather than one is \$200 million per vessel.

In addition to insufficient learning curve efficiency, we observed other sources of inefficiency. During visits, personnel at several yards mentioned real estate constraints, which preclude laying out production lines in the optimal manner. Executives at most U.S. yards visited stated that they have invested in capital improvements to improve efficiency, and personnel at the big six yards said that it is now easier under Northrop Grumman or General Dynamics ownership to obtain the capital required for large-scale improvements. Despite this, we observed significant differences in the levels of automation at U.S. yards. Moreover, according to personnel in Australia, U.S. domestic market protection decreases U.S. competitiveness and innovation, makes firms complacent, and discourages efficiency improvements to decrease costs.

Navy procurement instability and changing requirements. According to the National Shipbuilding Research Program Executive Control Board, "[a] business relationship characterized by stability and predictability is essential to future affordability and to preserve specific critical skills in an industry struggling to maintain skilled employees and capabilities, given the gaps in contract awards and low order quantities" (Zimmerman & Bissell, 2005, p. xi). During visits to U.S. yards, manufacturers consistently emphasized that stable, predictable orders are essential to controlling costs and retaining a skilled workforce. They gave examples of the government providing expectations and/or contracts with desired production numbers, only to have the numbers changed multiple times. This causes funding unpredictability, makes it difficult to plan, discourages investment in new equipment, and increases costs. While in Australia, the team visited the ANZAC program, a two-decade long acquisition project that produced ten naval vessels. Government personnel and contractors stated that it was the most successful ship procurement in Australia's history and was on schedule and budget. Both parties largely attributed this to adhering to the originally defined plan (the required number of vessels and technology for each did not change throughout the program). Because the contractor trusted

the government to stick to the plan, the company established contracts for all required steel and other items for ten vessels at the start of the contract, saving vast sums of money.

Members of the shipbuilding industry told us that in addition to changes in ship production numbers, the U.S. Navy also submits numerous change orders for vessels following “final” design approval. This significantly increases costs. Personnel at yards that perform both defense and commercial work compared the two customers and their acquisition processes. Commercial customers strictly limit changes and make decisions quickly, enabling U.S. shipbuilders to deliver vessels on budget and on schedule. The U.S. Navy has more people involved in the acquisition decision process, a complex requirements process, and multiple constituents. Thus, the government submits numerous (tens of thousands for larger vessels) change orders during the construction of each vessel and takes longer to make decisions. One industry member told us that every Navy ship is like a lead vessel (the first produced in a class) because of the quantity of changes desired during production. This significantly adds to the cost of production.

Technology insertion. Based on comments from U.S. Navy and industry personnel, the U.S. defense shipbuilding sector produces high quality, technologically advanced ships. However, in order to remain at the forefront of advanced technology utilization, the Navy often requests technology insertion that is not mature. This adds to costs, and as a result, technology and systems now account for over one-third of the cost of a naval vessel. Some shipbuilders advised us that the Navy should carefully consider the technology requirements because the Navy may be more effective by procuring more vessels (at lower cost each) that are not quite as advanced.

Political interventions. Political factors strongly influence the shipbuilding industry. Because Navy procurement contracts have significant employment and economic impacts on local areas, elected officials strive to ensure that naval ship construction and repair occur in their districts. This can lead to political infighting, procurement preferences, and production in multiple shipyards when it would be more efficient and cost effective to produce in one. Virginia class submarines are constructed in two yards, with modules transported by barge between them.

Workforce Issues

A U.S. Commerce Department study (2001) states, “This skill base of the U.S. shipbuilding industry is eroding, notably for welders, pipe fitters, and ship fitters. Shipyards also cited shortages of machinists, electricians and marine engineers” (p. 5). We found this to be true during visits, and managers at U.S. yards expressed concerns relating the workforce. The most common shortages were pipe fitters, welders, and electricians (plus nuclear welders at yards requiring this skill). One yard is approximately 280 personnel short each day. Despite this, except for yards impacted by hurricanes in the Gulf region, none of the firms had to decline business due to labor shortages. Yards in the Gulf have severe labor shortages due to personnel displacement and because workers in the area can now earn higher wages in construction.

For most firms, shortages exist because U.S. firms find it difficult to recruit young people to work in shipyards, and it takes four to six years and over \$50,000 each to train laborers to a minimal level. Furthermore, it is difficult to retain qualified, skilled laborers. Managers expect the situation to deteriorate because the workforce at most yards is aging (average ages ranged from 42 to 49 at those visited). To meet demands, one firm hired 500 Mexican workers. We also observed that many firms in the U.S. have established apprentice programs to train future employees, and state and local governments often support these. Australian yards are facing the same challenge and are addressing it with training programs and by hiring foreign workers.

Outlook

This section looks at the outlook for the commercial and defense sectors, including projected demand and the industry's capability to meet commercial and national security requirements.

Commercial

Short term (1-5 years). During visits to U.S. shipyards that engage in commercial construction, managers advised us that the yards currently are producing at levels well below capacity. Managers at these facilities also stated that they have not yet received orders sufficient to increase capacity utilization within the next five years. Thus, they do not intend to make new capital investments in the short-term due to a lack of demand to justify doing so.

Long term (5-20 years). Although foreseeable developments over the next two decades are unlikely to generate enough increase in new production to take up the existing slack in production capacity, two factors may increase future demand for U.S. built commercial vessels. First, the Oil Pollution Act of 1990 (OPA-90) requires all tankers entering U.S. ports to be double-hulled by 2015. As shown in Figure 1, the U.S. commercial shipbuilding industry will need to recapitalize Jones Act trade ships since U.S. firms built few ships after the elimination of federal subsidies in the mid 1980s. Estimates show that commercial shippers will need to replace 36 crude carriers, 67 product tankers, and numerous articulated barges. The U.S. commercial shipbuilding firms will need to ramp up and recapitalize (e.g., pipe and fabrication shops) to meet the increased demand. Second, the Department of Transportation predicts maritime traffic on U.S. waterways will double in the next twenty years (U.S. DOT, 2001, p. 4-22).

During visits to U.S. yards, we discussed their need to ramp up to recapitalize the Jones Act fleet. We found that there is a standoff between yards and customers. Shipyard executives are unwilling to make the necessary expenditures in required capital without orders to justify the expenses. Customers, however, are waiting to place orders for needed vessels. One shipbuilder expressed concern that customers may wait until U.S. firms are unable to meet the increased demand on time to comply with OPA-90, and then they will request a Jones Act waiver.

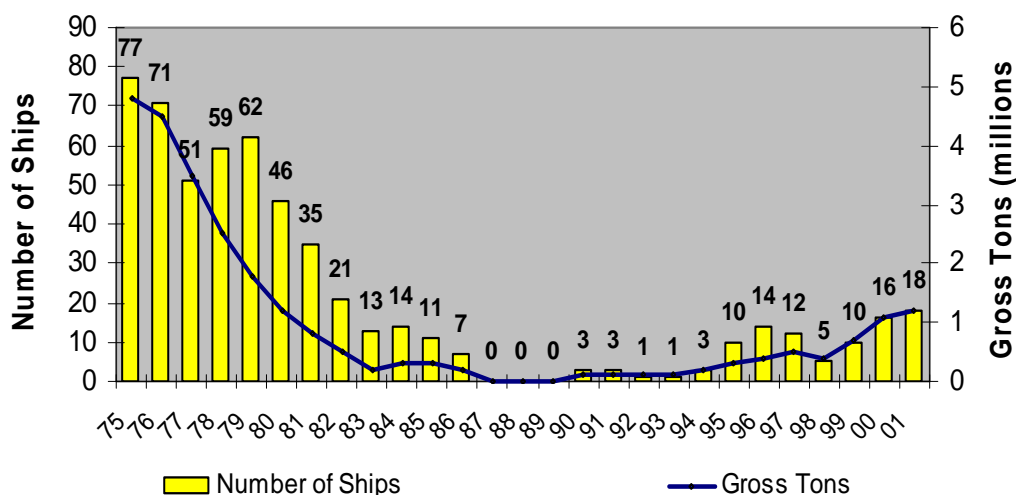


Figure 1. U.S. commercial shipbuilding orders (over 1,000 gross tons) (U.S. DOT, 2001)

Defense/ National Security

The outlook for the defense sector depends almost entirely on U.S. Navy plans. In order to meet current and emerging demands, the Chief of Naval Operations recently published a shipbuilding plan to increase the fleet to 313 ships (Mullen, 2006). Specifics of the plan include eleven aircraft carriers, 88 cruisers and destroyers, 55 littoral combat ships, 31 amphibious ships, a Maritime Prepositioning Force (Future), and 48 attack submarines. The USN also may increase attack submarine production to two per year to reduce the average cost per hull (O'Rourke, 2006c, p. 2). See Essay 2 on Virginia class affordability.

Although U.S. defense shipbuilders produce the most capable vessels in the world and meet performance expectations, they generally do not meet cost and sometimes do not meet schedule expectations. In addition, because the firms are profit-driven, executives only invest in capital improvements if there is sufficient financial incentive and cannot be counted on to retain the workforce as an important national asset unless the workload justifies doing so. Despite these issues and the noted challenges, representatives at U.S. yards and an industry association stated that U.S. firms could meet the increased demand associated with the Navy's 313-ship plan. Undoubtedly, the industry supports this initiative and welcomes the possibility of a stable plan.

Based on visits, there is certainly sufficient plant and equipment capacity to support the Navy's expected increase in demand, even if some of it is aging and inefficient. One impediment to meeting increased demand or surge potential, though, is skilled labor shortages. Firms are aware of this and many have apprentice and training programs to recruit and train the necessary workforce. Many also have partnerships with educational institutions and receive local and/or state government financing to support these efforts. Although yards are making efforts to improve efficiency and reduce costs, most are not aggressively doing so. They have become comfortable depending on the Jones Act to support higher prices or on DOD's willingness to pay for cost overruns. Therefore, most firms in the industry do not have a good strategy to become competitive in the global market. In the defense sector, the strategy is to blame foreign competition and the U.S. government for their problems and then lobby Congress to continue to keep all existing yards alive. Congress obliges by mandating requirements that add to costs.

Government: Goals and Role

To the extent the commercial sector supports the defense sector and adds value to the economy, the government should support it. Naval vessels are vital to national defense, which is a public good, so the U.S. government has a responsibility to provide them. Doing so in sufficient quantity to meet expanding missions requires that vessels be affordable. Based on visits and discussions with experts, there are at least five overarching government policy options for the industry: nationalization, a government owned/contractor operated arrangement, enhanced government support/subsidies, laissez-faire, and consolidation. This section evaluates each based on ability to provide improvement in five areas: cost, schedule, performance, capital equipment, and development/retention of a skilled workforce.

Nationalization

One option (applicable to the defense sector) is nationalization. The government would own the factors of production and operate yards building naval vessels. This would help ensure maintenance of the desired capacity. However, because this option runs counter to U.S. values, it would face significant challenges, such as political opposition and initial costs to procure desired facilities. Moreover, government-run entities have a history of performing worse than private

ones. Australia has a government-owned yard. During a visit, we learned that the government is attempting to privatize it, and personnel stated that it is not as efficient as private yards. However, since experts believe the U.S. industry is in crisis, officials should consider all options.

Public yards would not have to earn a profit, thus reducing this portion of cost. The effect on total costs would depend on whether public yards could achieve sufficient levels of efficiency. Efficiency would also be an important determinant of ability to meet schedule requirements. However, depending on cost pressures, public yards may be more flexible in hiring larger numbers of workers to meet requirements. Based on visits to two public yards, they could meet performance requirements. Depending on the national fiscal situation, public yards may be more willing to invest in major capital improvements and could depend on the U.S. government for desired funds. Nationalized yards could also ensure retention of a skilled workforce.

Government Owned/Contractor Operated

In a Government-Owned Contractor-Operated (GOCO) situation, the government owns the shipyards and equipment, and private firms operate them, as in China. In the U.S., Aker leases Philadelphia Naval Shipyard real estate from the government for only \$1 per year.

Although this option would reduce the costs of private firms and should thus reduce prices, used alone, it probably would not reduce total costs to U.S. taxpayers or change ability to meet schedule or performance expectations unless the government significantly upgrades capital. Improvements to capital would probably be as discussed under the nationalization option. Since operations would be contractor run, workforce retention and development would depend on the effect on profits. This option could face challenges similar to those for nationalization.

Enhanced Government Support/Subsidies

The USG and state and local governments already provide substantial support (subsidies) to U.S. yards. The state of Virginia paid for the construction of a reception and training center for Newport News Shipyard, the city of Mobile and state of Alabama paid for training programs and buildings for Austal USA, and the USG reimbursed firms for capital improvements. One policy option is for the government to enhance support/subsidies to the industry. For example, the USG could fully fund the Title XI loan guarantee program, increase tax incentives, accelerate depreciation allowances for capital investments, expand the capital expenditure (CAPEX) program, which reimburses firms for expenditures on capital improvements that reduce costs, and increase grants and loans. Expanding support/subsidies could create growth; however, the U.S. would need to be careful not to provoke retaliation by other nations or a trade investigation.

Although this option should decrease private firm costs and prices paid for naval vessels, it would not necessarily decrease total costs to the U.S. government for naval vessels. However, if such support enables the U.S. shipbuilding industry to supply vessels to a larger customer base (including those outside the U.S.), this would increase production, improving efficiency and reducing costs. Furthermore, with expanded output, firms would improve production processes, enhancing ability to meet schedule requirements. Expanded production could also enhance performance as firms would hire more designers and engineers and invest more in research and development. With an increased customer base and revenues, firms would also be more likely to invest in capital improvements and human resources. Although this option would not guarantee retention of needed skills, it may expand the workforce available.

Laissez-faire

This option differs from the others because it eliminates government intervention and leaves ship construction and procurement to the international free market. The USG would eliminate the Jones Act and industry support and buy naval vessels based on best value in the global

marketplace. This is not a viable option if the U.S. desires to maintain the capability to build ships. However, it is an option if the U.S. only desires *access to ships*.

The first issue with this option is whether firms outside the U.S. can build USN ships, and it appears they can. Many overseas yards use the latest technologies and processes and build ships faster and cheaper than U.S. yards. To meet International Maritime Organization and Australian environmental requirements on schedule and at an acceptable price, the Royal Australian Navy replaced an underway replenishment vessel by purchasing a tanker produced in South Korea and modifying it. Even with modifications, it cost less than a third as much as manufacturing it in Australia and took less than one-eighth the time to build. The Australians said that it is reliable, provides the desired capability, and is as good as ships built in Europe.

Another argument against overseas construction of naval ships is that access could be taken away, leaving the U.S. without the capacity to build ships when needed. This is unlikely since there are many yards in nations that are allies, and it is unrealistic to assume all of them would simultaneously turn down revenues and deny access. The notion that it would be too late if the U.S. were suddenly at war ignores the fact that it takes 3-5 years to build naval vessels in the U.S. Any ship requested at the outbreak of hostilities would not be available for the conflict.

Free market competition would allow the U.S. to purchase vessels from suppliers with much lower costs, thus decreasing prices. Even purchasing hulls overseas and adding the systems in the U.S. could reduce costs. Because overseas yards produce many more vessels than U.S. yards and consistently meet the strict schedule requirements of commercial customers (e.g., cruise lines), this option would improve ability to meet schedule expectations. Except for submarines, open competition should meet performance requirements, especially for hulls. Under this option, the U.S. government would not need to ensure retention of a workforce or infrastructure.

Based on information received during visits, U.S. firms that build commercial vessels would no longer be able to do so under this option. In fact, the continued existence of shipbuilding in the U.S. would be doubtful under this option. If the industry survived, it would have to consolidate significantly, eliminating redundancy. As visits to yards affected by hurricanes in the Gulf revealed, relying on only one manufacturer may not be wise for a strategic industry.

Consolidation

This option entails reducing the number of yards. Since it is mainly a policy option for the defense sector, it would result in constructing naval vessels at fewer facilities. This option would reduce costs by reducing excess capacity and overhead costs. The increased throughput at the remaining yards would improve economies of scale and learning curve advantages, further decreasing costs. By concentrating work at fewer yards, the remaining yards could receive a larger share of government and private investment in capital equipment and infrastructure. This would allow the U.S. yards to procure desired (but currently unjustifiably expensive) equipment, such as the larger cranes in Korean yards, to build larger modules, thus improving efficiency and decreasing cost. These improvements would also benefit ability to meet schedule expectations. Focus on fewer yards may allow those remaining to increase investment in research and development, improving performance. This option may make it more challenging to recruit workers, but would improve the experience of the workforce at the remaining yards.

The team recommendations are in the conclusion section following the two essays.

Essay 1 (The U.S. Seagoing Services: Achieving More With Less)

Overview

Due to increasing missions in distant locations and expanding threats to the homeland,

demands on the U.S. Navy (USN) and U.S. Coast Guard (USCG) are increasing. At the same time, the USN fleet size is the lowest it has been since World War I, and the U.S. fiscal situation constrains funding for ship construction. Thus, the USN and USCG face the challenge of doing more with less in the coming years. Daniels (2005), observing that this situation is not unique to the U.S., states, “Military organizations around the world are under pressure to achieve greater operational output with fewer resources and reduced cost” (p. 77). Two proposals for the USN and USCG to achieve this are reduced crew sizes and use of mission modules aboard ships.

The Need to Do More With Less

Increasing Demands

Cebrowski (2005) states, “The new era, so far, involves frequent contingencies of a wide variety across a wide geographic arc against an assortment of adversaries” (p. 11). Contingencies “across a wide geographic arc” generally require ships to deploy forces and supplies and conduct operations to achieve national objectives. Furthermore, with 95% of U.S. and 80% of world trade traveling by sea, “maritime security is required to ensure freedom of the seas; facilitate freedom of navigation (FON) and commerce; [and] advance prosperity and freedom” (NSMS, p. 2). Unfortunately, the variety and number of threats to maritime security are expanding, increasing the demand for naval forces both far away and at home.

With 95,000 miles of shoreline, a 3.4 million square mile exclusive economic zone, and over 350 official ports of entry (USCG Maritime Strategy for Homeland Security), maritime security is also vital to U.S. homeland defense. With the U.S. in the midst of a global war on terrorism (GWOT), transnational maritime threats to the homeland are increasing in variety and number. This further increases demands on the U.S. Navy (USN) and the U.S. Coast Guard (USCG).

Resource Constraints

Ships. Despite the increasing demands placed on the seagoing services, the size of the Navy fleet continues to decrease. At 281 ships today, the size of the combat fleet is the Navy’s smallest since just before World War I (GovExec). Senator Warner even cautions that a fleet of this small size may jeopardize the Navy’s ability to meet its mission requirements (AP 2/8/2006).

Recognizing the national security implications of the increase in threats and demands in conjunction with a decrease in the fleet size, the Chief of Naval Operations (CNO) developed a 30-year shipbuilding plan, which outlines a strategy to build a 313-ship fleet for the Navy. He estimates that “an average of \$13.5 billion a year will be needed to sustain it through 2020, an average of about \$4 billion more than the Navy has gotten over recent years” (Cavas, 2006a).

Fiscal. Unfortunately, Office of Management and Budget projections through 2024 show “the smallest percentage of GDP for defense at anytime in our history, which bodes ill for increasing the Navy’s ship inventory to 313” (Krekich, 2006). “DOD’s budget faces growing pressures from increases in mandatory federal spending, [so] [i]t will be difficult for DOD to increase its budget share” (GAO, 2005). Truver (2005a) states, “In this increasingly austere fiscal environment, none of the U.S. armed services can afford all that they want or need” (p. 1). Thus, Cebrowski (2005) concludes, “The key issue facing the...Navy is that the available budgetary resources are not likely to be adequate to fund the existing plan” (p. 23).

Likewise, “several naval budget analysts...cautioned that the new fleet plan is unaffordable” (Cavas, 2006b). Eric Labs, Navy analyst for the Congressional Budget Office, asserts, “[T]he Navy would have to spend \$20.9 billion per year in 2007 dollars at a steady state over the next 30 years in order to ‘fully fund the requirement for a 313-ship fleet.’ Even to sustain today’s fleet size of 280 ships, the Navy would require about \$14.7 billion annually” (Sirak, 2006). He also

warns, “If investment levels for Navy shipbuilding do not increase to some degree in the coming years, the fleet size will decrease to roughly 200 ships” (Castelli, 2006).

In light of the fiscal dilemma, even the CNO concedes that the Navy’s total budget will not grow much, requiring ship funds to come from elsewhere in the Service’s funding (GovExec). O’Hanlon (2005) says the pressure on procurement funding indicates the need to economize wherever possible (p. 72). Thus, the seagoing services may need to do more with less for many years. Two options for achieving this, both of which have implications for the shipbuilding industry, are reduced crew sizes and use of interchangeable mission modules aboard ships.

Reduced Crew Sizes

Description

“It is universally agreed that the single greatest contribution to a modern warship’s cost, once in service, is that of its personnel” (Andrews, 2003). As a result, analysts point out that the fiscal pressures on Navy shipbuilding will only worsen because outlays on personnel costs are exploding (Ahearn, 2006b). Therefore, reducing personnel costs could be an option for increasing shipbuilding funds. Accordingly, “[t]he 2007 budget calls for a reduction from 352,700 sailors at the end of this year to 340,700 by the end of 2007” (Scutro, 2006). Because of this, there will be fewer personnel to operate each ship, as reflected in projected crew sizes:

The DD(X) destroyer would have about 100 to 130 crew, versus more than 300 on the old Arleigh Burkes; the new Littoral Combat Ship (LCS) would have a combined total of about 70; and the CVN 21 aircraft carrier would have about 1,500 fewer personnel than the combined 5,500 total on the old Nimitz Class carriers (ship and air crews). (Ahearn, 2006b)

Cebrowski (2005) states, “Reduced manning on ships has significant payoffs in reduced costs, reduced ‘hotel’ loads affecting ship size, a higher payload fraction and fewer personnel at risk in high threat environments” (p. 45). This would certainly contribute to achieving more with less; however, there are some challenges. Speaking about the LCSs, RADM Buzby (USN Deputy Director of Surface Warfare) says, “One challenge facing the Navy will be how to carry out the...missions with a ship crew of 40, a dedicated mission module crew of 15 and an air crew detachment of 20” (Fein, 2006a). The shipbuilding industry may be able to help meet the challenges associated with reduced crew size. In fact, there are several implications for industry.

Implications for the Shipbuilding Industry

Understanding the need to reduce personnel costs, shipbuilders should design vessels for smaller crews. This may affect payload, sustainability, automation, and survivability.

Payload. According to Cebrowski (2005), with reduced crew size, “[p]ayload fraction can increase from less than 10% to over 30%” (p. 2). This has some interesting design implications. For example, vessels would have added space for storing fuels and other consumables. This would allow ships to remain on station longer and reduce the amount of time spent transiting and replenishing supplies, improving “productive” use of “capacity.” Although operating and personnel costs could be lower, smaller crew size does not necessarily reduce ship procurement costs. Thus, industry may need to help the Navy explain the long-term cost benefits to Congress.

Sustainability. RADM McCullough (USN Director of Surface Warfare) says that with reduced crew size, “[t]he crew isn’t large enough to do preventive maintenance on the ship” (Fein 2005a). Currently, preventing corrosion in the marine environment is human resource-intensive. Thus, the industry should improve the sustainability (including availability, reliability and maintainability) of future ships (Andrews, 2003). For example, industry could continue to develop better coatings and materials that will not deteriorate in salt water to reduce the

preservation work required. Crews also spend many hours performing preventive maintenance on ship systems, so engineers should design future systems to minimize these requirements.

Noting one option for reducing requirements, Cebrowski (2005) proposes, “Significant payoff ...could be realized in an ‘all electric’ ship in which centrally generated electrical power provides not only propulsion but also energy for ship operations, communications, surveillance, and even weapons modules” (p. 44). Andrews (2003) describes possible design considerations:

The advances and cost efficiencies adopted in the latest cruise ships can be readily incorporated...Full electric propulsion will cover the total power generation, enabling the number of prime movers to be significantly reduced. The UK’s Electric Ship program further envisages elimination of extensive hydraulic systems that exist in current ships, and their replacement in the electric ships of the future with local electrical actuation. This will mean a lower maintenance demand. (pp. 3, 4)

Automation. Just as manufacturing plants use automation to decrease labor costs, naval ships may need more automation to operate with fewer people. A commercial shipbuilding industry report states, “Newer ships are designed to be operated safely by smaller crews. Innovations include automated controls and computerized monitoring systems in navigation, engine control, watch keeping, ship management, and cargo handling” (IbisWorld, 2006, p. 35). Cebrowski (2005) adds, “Computer driven dynamic control surfaces can augment ship speed and stability. Automation can also be incorporated to assist decision-making established networks, and in the operation of weapon systems” (p. 45). However, as each sailor must perform more tasks with smaller crews, automation must be user-friendly. RADM McCullough elaborates, “One sailor will have to handle the skill sets of several sailors, for example becoming an electronics technician, fire control technician and information technology technician” (Fein, 2005b).

Survivability. With fewer people aboard to repair damage and casualties, engineers should strive to improve ship survivability. Obviously, the best way is to prevent damage in the first place. Cebrowski (2005) recommends designing ships with greater speed, maneuverability, and smaller signature so that they can elude detection, tracking, and strike by an enemy (p. 51). Andrews (2003) notes that stealth features contribute directly to warship survivability and suggests engineering the above-water structure and designing the propulsion system and auxiliary plant to minimize the vessel’s acoustic signature. He suggests shipbuilders employ “increased use of radar cross-section reduction and of intelligent composites and further adoption of integrated upper-works features” (p. 3). Although these ideas would improve survivability, engineers should develop systems to repair damage swiftly and easily if it does occur. Methods currently used aboard naval ships may be too human-intensive for ships with fewer personnel.

Interchangeable Mission Modules

Background

The Royal Danish Navy (RDN) developed the novel Standard Flex system of modular mission payloads for their Flyvefisker-class multi-role surface combatants (Scott, 2004).

The underlying principle of the concept is the use of standardized containers to enable the rapid interchange of role-specific weapons and equipment. Containers are lifted into wells in each ship, with standard interface connections providing access to the ship’s services. [It is germane to note that the concept was] originally conceived during the early 1980s at a time when one-for-one replacement of existing units was deemed unaffordable. [RDN Admiral Wang professes that] [t]he use of the Standard Flex modules helps us to reduce both procurement and maintenance costs. (Scott and Toremans, 2005, pp. 2, 10)

Advantages

Possible advantages to the USN include cost decrease/asset utilization increase and flexibility.

Cost/asset utilization improvement. RADM Buzby describes the current dilemma created by technology changing more quickly than the USN replaces ship hulls:

The combat system on many surface ships is outdated or is no longer able to meet threats or projected threats. Now you are stuck with a hardwired-in combat system that you now have to upgrade at a tremendous expense, and...you've now taken that ship out of the fleet for up to a year while you are ripping stuff out and putting it back in. (Fein, 2006b)

However, decoupling the hull from the sensor, weapon, and mission modules can reduce costs to upgrade for technology advances and prevent time off-line. Cavas (2006c) conveys, "A major advantage is that improvements in capability can be made in the modules, rather than taking the ships out of service for expensive upgrades." For example, in the LCS, the forward gun and self-defense system missile launcher will be modularized to allow easy refit by future weapons (Truver, 2003). With fewer ships and increasing demands, reducing time off-line is essential.

Flexibility. Interchangeable modules enhance flexibility, enabling vessels configured with this capability to perform a greater variety of missions and adapt to changing technology and threats. This is valuable considering the dynamic security environment and pace of technology change. Montroll (2002) imparts, "Weapons, tactics, and strategies that were introduced into one conflict may be decisive factors in the next war and be mainstream tools by the following one" (p. 347).

The RDN uses modules so that a small number of ships can "span almost the full spectrum of military tasks, right through from low-risk, low-intensity humanitarian and peace support operations to high-intensity sea control" (Scott, 2004). Cebrowski (2005) summarizes:

By providing naval commanders with the ability to rapidly swap out modules that endow platforms with different capabilities, the fleet can adjust promptly to the wide spectrum of challenges it could face. These modular platforms can be reconfigured to tailor the capability to focus on the immediate operational needs. The fleet can with the same number of total hulls, respond to a broader range of challenges. (pp. 7, 50)

The new USN LCS is an example of a U.S. vessel that will use interchangeable modules; the design will make about 40 percent of the payload volume reconfigurable (Bruno, 2006). Noting that this will enhance flexibility, Delores Etter (a USN assistant secretary) declares, "The missions that the LCS can perform will be essentially unlimited, because of interchangeable mission modules that can be on-loaded or off-loaded... [Thus,] the LCS will play far more roles than...originally expected" (Ahearn, 2006c). The USN originally planned for LCSs to conduct three missions - mine counter measures, anti-submarine warfare, and anti-surface warfare. Based on the flexibility provided by modules, naval planners now expect to add missions, such as GWOT/maritime interdiction, disaster relief, and search-and-rescue. Admiral Vern Clark, while serving as CNO, said, "Think about what this will mean to our 'National Fleet' partnership with the Coast Guard. Now I don't have to build in homeland security capabilities, as I can tailor the mission modules when we work with the Coast Guard" (Truver, 2005b).

Implications for the Shipbuilding Industry

RADM Landay (USN) observes that developing combat systems separately from hulls is "a radically different approach to designing, engineering and building a complex warship" (Truver, 2005b). Therefore, use of modular mission packages could have profound implications for the shipbuilding industry. However, because of the need to do more with less and the potential benefits of this concept, the shipbuilding industry should embrace this idea and continue to invest in designing improved modules and developing new uses for the concept. Furthermore, based on the rapid pace of technology change, the industry should develop plans to upgrade

module inventories (once the USN has an inventory). The industry should also work with the USN to expand the modularity concept to larger vessels. In fact, “[RADM] Buzby said it would be fantastic to be able to apply LCS’ capability into bigger ships. It would keep the Navy’s capability up and it would be a lot less expensive than what the service does today” (Fein, 2006b). In addition, industry should develop methods to change modules at sea, with support from a sea base or logistics vessel, to optimize operational employment of vessels once on-scene.

The modular concept also offers benefits to the shipbuilding industry. For example, it provides opportunities for growth and new development that may allow the industry to reinvent itself and move from the mature/declining lifecycle phase to a more favorable phase. It would also allow shipbuilders to produce common “families” of ships (just as Boeing produces “families” of planes (HBS, 1991)) to serve a variety of customers with the same hull. Naval shipbuilders may even be able to leverage the concept to attract commercial and foreign customers. This would increase the number of each hull produced, improve economies of scale, accelerate learning, and decrease costs. One positive sign supporting this is that twenty-six nations “have voiced interest in their own nation-specific mission modules” (Bruno, 2006).

Moreover, decoupling ship hulls from the sensors and weapons systems that involve more rapidly changing technology could reduce the technology risk associated with buying ships. This would decrease unexpected cancellations and changes to orders. This, in turn, would improve production stability, which would also help to control costs. Explaining the decreased risk, the prospective commanding officer of LCS-1 says, “[M]odularity will make it possible to reconfigure LCS without having to wait until some particular time in its life when it can be taken into dry-dock” (Fein, 2005c). Finally, since modules do not have to be built in shipyards, they could be manufactured in multiple states. This could mitigate industry concern over skilled labor shortages and generate added congressional support and funding for shipbuilding.

Conclusion (Essay 1)

Faced with growing threats, uncertainty, and demands for their services despite shortages and constraints on future procurements, the U.S. seagoing services must strive to accomplish more with less for years to come. Two options that may enable these services, with support from the shipbuilding industry, to achieve this and better use funds and assets are reduced crew sizes and use of interchangeable modules aboard ships. Therefore, the USN, USCG, and industry should embrace these concepts and work together to apply them when developing future ships.

Essay 2 (Virginia Class Submarine Affordability)

Introduction

The Seawolf Class submarine, SSN-21, is in many respects the most capable and heavily armed fast attack submarine the world has known. So why did we stop making them? The answer is clouded by the high cost, underestimated demand, and dwindling threat at the end of Cold War. These issues resulted in stalled production for over a decade, and assured that a bow-wave submarine production would be required to sustain force levels. Virginia Class Submarines (VCS) were to be the affordable alternative to Seawolf to meet this demand. They were also a new fast attack submarine that would meet the changing strategic requirements placed on the submarines expected to replace the aging Los Angeles Class (SSN-688) fleet. Somewhere in the plan, however, with the limited number of VCS being built, the cost is about the same as Seawolf. Government budgeters must get beyond the price tag, and incorporate the lessons of the Seawolf program to balance affordability and capability. Failure to build a sufficient number of capable submarines commensurate with mission demands risks the nation’s security.

Seawolf, the most capable submarine ever built

With the Navy's approval of 15 of 29 Seawolfs in the late 1980s, shipbuilders geared up supply lines and improved production lines to deliver a capable yet affordable deterrent to an increasing Soviet threat. Through economies of scale, the reduction in cost per unit realized through multiple production proficiency, the cost of each additional unit would lower as more were produced. The advertised cost of the 29 SSN-21s was about \$1.9 billion each.

In January 1989, the USG awarded Electric Boat the first contract for SSN-21 and expected the unit cost of the following three Seawolf submarines to decline such that the fifth and following ships would not exceed \$1.3 billion in 1990 dollars. This included a plan to contract the first 15 before delivery of the lead ship Seawolf in 1995 (Conahan, 1990, p.3). With the fall of the Berlin Wall in 1989, and later the Soviet Union, the requirement to counter the Soviet threat was no longer applicable. Driven by the belief that Seawolf's high cost would lead to inadequate submarine force levels to meet projected missions in other areas, in 1991, Congress suspended the program. Since Congress had previously approved the program, three Seawolf submarines were approved in an effort to bridge the gap in the submarine construction base until DoD could establish a requirement and design for a more affordable fast attack submarine.

Virginia Defined, the New Affordable SSN

Congress directed a study into the Virginia and Seawolf program costs in 1994. The study concluded that in 1994 dollars, the procurement costs for the Virginia were \$1.5 billion each as compared to Seawolf's \$1.9 billion each. The assumptions to the study also recommended that five management lessons from prior submarine construction programs be incorporated: First, the ship was to be contracted with a single shipyard to design and construct the lead submarine. Second, the lead ship construction was to be delayed until Virginia's design was mature. Third, the specification and approval process was to be strengthened. Fourth, supply vendors for key critical components were to be identified early. Fifth, the fire control system development risks were to be reduced and targeted for an additional savings of \$90 to \$100 million each (USGAO, 1994, p3). The study also defined that Virginia was to have many of the same capabilities as Seawolf along with adding a much needed special operations forces capability. Virginia was also to be as quiet as Seawolf, include a vertical launch system similar to second flight 688 Class submarines, and have improved surveillance and special operations characteristics to enhance operations in the littorals. Additionally, Virginia would be the first submarine equipped to carry unmanned underwater vehicles at delivery. All of this was at a lower cost than Seawolf.

The Original Plan. The Navy's original plan approved in 1995 was to build one Virginia in 1998, a second in 2000, and then two per year beginning in 2002. All ships were to be built at Electric Boat Corporation, Connecticut as a single source in attempt to keep costs lower than procuring ships through two different yards. Congress rejected this plan in 1995 following a Bottom Up Review which stated, "delaying construction of CVN-76 would threaten the viability of the Newport News Shipbuilding shipyard due to the lack of work ... (but) could be minimized by rescheduling ship overhauls, delaying delivery of carriers currently being built, and assigning other work to the shipyard" (USGAO, 1995, p.4). In essence, Congress directed that Newport News be integrated into the Navy's plan for the construction of future VCS.

Plan Update #1. The National Defense Authorization Act for FY1996 changed the Navy's original plan and directed that one VCS be delivered each year 1998 through 2001, alternating years between Electric Boat and Newport News. The design was to be used by both contractors, each of which was to propose improvements so that "each successive submarine is more capable and more affordable, and that the design for a future class of nuclear fast attack submarine will

incorporate the latest, best, and most affordable technology” (Library of Congress, 1996). The Navy stated that using two shipyards would increase the cost of 30 VCS by \$3 billion. In 1996, the two shipyards proposed to construct Virginia as a team rather than as competitors. This fulfilled Congressional direction for both nuclear submarine shipbuilders to be involved in construction and design improvements (Federation of American Scientists, 2006).

Under this plan, each yard was to specialize in certain areas of the submarine and ship that area to the respective delivery shipyard. The goal was that each shipbuilder would specialize in certain modular subassemblies and approach economies of scale within that subassembly while not taking away the industrial base to build submarines from either shipbuilder. The National Defense Authorization Act for 1998, Public Law 105-85, approved the teaming concept. This arrangement did not necessarily mean that each yard was fully redundant of the other, it only assured that each yard was capable of full construction without starting from scratch.

Problems on the horizon. In a 1998 GAO letter to the Secretary of Defense, the GAO noted in the Navy’s updated plan to build 30 VCS for \$64 billion (\$2.13 billion each) that technical and funding limitations resulted in several subsystems (including the electronic warfare and acoustic intercept systems and other subsystems) having performance below optimal levels. The GAO also noted that the previous Navy threat assessments of open ocean anti-submarine warfare enemy had changed and the enemy’s capability had improved (GAO, 1998).

Additional problems were noted in the external communications, weapons delivery, and towed array systems, and meeting the propulsor’s cavitation design goals. These issues along with the increase in global submarine numbers caused the Navy to constantly reevaluate the design. Contrary to one of the original five lessons learned to keep Virginia Class construction costs at a cost below Seawolf, the Navy again changed the requirements and escalated the program’s costs. The GAO also concluded that the Virginia program was not likely to meet the objective of producing a significantly lower cost submarine than Seawolf.

Plan update #2 and more... In light of this new intelligence on the threat, the Floyd D. Spence National Defense Authorization Act for FY2001 authorized five additional VCS to be procured during 2003-2006, and directed a report for a plan to maintain at least 55 fast attack submarines through 2015 driven by the Joint Chiefs of Staff Submarine Force Structure Study. The 55 submarines were to include 18 VCS by 2015. The Act also directed an assessment to increase production to two per year in 2004 or 2006 and prevented decommissioning any 688 or Ohio Class submarines. The following two additional VCS were added to the original plan to be procured through 2007. Shipbuilders were seeing changes to class numbers on an annual basis.

The current plan. To date the Virginia Class plan has changed nine times since 1995, and the plan to increase the build rate to two per year has been delayed 10 years from the original plan to 2012. With that many changes, it is understandable that shipbuilders are hesitant to invest in automation and infrastructure improvements that would increase productivity and lower costs. Additionally, because of the low production rate of .5 submarines per yard per year, the two yards do not benefit from repetition and the application of lessons learned enough to cause a benefit and savings per ship that would occur with economies of scale.

Executives at Electric Boat state that special operations design changes to the third Seawolf, USS Jimmy Carter, along with four Trident SSBN to SSGN conversions have bridged the workload gap to maintain an adequate workforce required to start the two per year construction of the VCS. Jimmy Carter’s work was completed in 2005, and the SSGN conversion work is winding down over the next year. This will leave Electric Boat’s workload at a slim .5 submarine per year. Added layoffs are expected while waiting for the increase in build rate that the Chief of

Naval Operations' (CNO's) plan states. One would assume that cost would also be reassumed later to gear production lines back up and retrain additional workers to meet new demand.

CNO's 313 ship Navy. Starting in 2012, the CNO's 313-shipbuilding plan includes returning to a steady-state production rate of two VCS per year, while achieving an average hull procurement cost of \$2 billion (OSD-QDR, 2006, p 48). Although this plan appears to be increasing the capability of the Navy in the littoral region, this robust and stable plan cuts short the need for submarines. An analysis of the Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2007 shows that after 2019, the inventory of SSNs will fall below 48 SSN force in 2020. Further, the total number will not rise again to 48 until 2034.

Given that it takes five years from start to delivery for VCS, one could conclude that increasing the build rate to two in 2009 would lead to the bottom line number of 43, and starting in 2007 would lead to a bottom line number of 45, thus not meeting the QDR's 48 requirement. One could also question the similarity to the British government's trouble in maintaining a viable submarine industry with the construction of its new submarine HMS Astute. These problems were caused when at the end of the Cold War the Royal Navy reduced the submarine force and its industry. As a result, Britain did not maintain a design or industry base to support submarine construction during the downsizing of its force and suffered the consequences. While attempting to bring design and production lines back, the British found that the shipbuilding industry had lost the capability to do so. As a result, the British had to ask Electric Boat designers for help (Work, 2006, p8). If similar problems occur in the U.S., there will be no one to turn to.

One also has to question the decision to lower the total number of SSNs that we produce given an ever increasing and competent submarine threat. It does make sense that "with over 400 submarines in the world today ... this global proliferation of submarines clearly poses the greatest threat to that maritime security...a threat that has gone too long with too little focus, investment, and training" (Konetzni, 2006, p2). The U.S. must therefore look toward not only the strategic implications of maintaining a robust submarine building capability, but look towards building sufficient numbers of submarines to meet the threat.

The Warfighting Requirements

The 1999 Chairman of the Joint Chiefs of Staff study on Fast Attack Submarines evaluated the SSN missions required by the Combatant Commanders (COCOMs). Because of this study, the Senate Armed Services committee required that the Secretary of Defense submit a report with submission of the FY02 President's budget to meet the requirement of maintaining at least 55 SSNs through 2015 and a plan to achieve 18 VCS by 2015.

This study was conducted in more detail than most force structure studies since it reviewed prior studies. It was "conducted by personnel drawn from various military services, [and] took into account several years of operations and experience with the Navy's post-Cold War missions [but] did not take into account information about the extent of China's naval modernization effort that has come to light since 1999" (O'Rourke, 2006d, p. 21). VADM Konetzni also noted, "Some ten years ago, some well respected strategist said this: we can conclude that during the First World War, the dominant vessel was the battleship, and in World War Two, it was the aircraft carrier. In future global wars, the most powerful and decisive weapon will be the submarine. The problem is that these were not American, they were Chinese" (2006, p. 2).

Of the eighteen submarines that were commissioned last year, the Chinese built twelve while the U.S. only built one. China is outpacing the U.S. production of submarines by at least five times, and it is incorporating tactical design features that mimic the best U.S. submarines. Additionally, China's diesel submarine force is among the most quiet and capable of all

submarines at sea today. These alarming trends and calls for a more robust submarine force cannot be oversimplified. The U.S. must find a way to fund a capable submarine force. The 313-ship plan that lowers the total number of SSNs will not be sufficient to deter, compel, and, if necessary, defeat the twenty-first century forces arrayed against our interests.

Recommendations (Essay 2)

Stable, two per year plan now. The U.S. shipbuilders must be guaranteed a steady two per year construction rate with no more changes. This needs to be as soon as possible before the labor numbers and production capability of the yards lowers and SSGN work comes to a close. The shipyards must also be guaranteed that the acquisition community will not require modifications to technical capabilities that drive up production costs. They are disruptive to the advantages of repetition and the lessons learned curve and are very expensive.

Return to one shipyard. The Seawolf construction program learned that a single shipyard should be used to minimize cost. Today the additional cost of maintaining two yards results in an additional \$.2 billion per ship. Some argue that the cost of teaching one shipyard the production of an entire ship would be more than the additional cost incurred of maintaining two, but when 25 more VCS are scheduled for delivery, the total added savings would fund two SSNs.

Incentive contracts. The shipyards have little incentive to reduce costs under the current contracts beyond the Capital Expenditure Program in which savings seem rare. History shows that when shipbuilding projects exceed projections, there is little repercussion, and Congress will always approve more money to cover additional cost. As a result there is little motivation to reduce costs. The builders must be provided additional incentives in their contracts to reduce the cost of each unit. Automation, activity based costing analysis, and studies on design changes that will lower costs will result in fewer hours of construction, less overhead, and lower costs.

Improve government and contractor vendor participation. Senior Electric Boat officials stated that the cost of each Virginia is broken into one-third shipbuilding, one-third Contractor Furnished Equipment such as valves and pipes, and one-third Government Furnished Equipment such as nuclear reactors, sonar equipment, and sensors. Cutting cost in the additional two-thirds similar to the methods in shipbuilding will also reduce the overall cost of each unit. Each of these activities must also be provided incentives to reduce costs.

Stop the decommissioning of Los Angeles Class ships. The U.S. is currently decommissioning Los Angeles Class SSNs at the 20+ year point for a ship that was designed to last 33 years. These assets are being retired early simply to afford the cost of buying new submarines. Keeping the two remaining ships in service will help improve the number of available SSNs to conduct missions and meet the warfighter's requirements as the Virginia production line ramps up.

Conclusion (Essay 2)

The U.S. must immediately change the current course in submarine production while forcing the industry to build an affordable Virginia. The Seawolf and Astute submarine program lessons learned must be realized so that the history of wrong decisions does not repeat itself. Given this, the current SSN build plan does not support the current projections of needed SSNs to counter the identified threat and in fact lowers as the threat rises. The real question should not be can we afford to build adequate numbers of Virginia, but how can the American people afford to live securely if we do not build more of them.

Conclusion

The U.S. shipbuilding industry is at a crossroads – it produces the best ships in the world, but at exorbitant prices that make the commercial sector uncompetitive and limit the number of ships the U.S. Navy can afford. Since the industry is complex and has multiple constituencies, there are diverse economic, political, and military solutions that have competing interests. In order to provide a recommendation, the study team first considered the fundamental issue of whether the U.S. needs to maintain an indigenous capability to manufacture ships. Because of the importance of the maritime domain to the nation, the U.S. should maintain an indigenous capability to build naval vessels. In addition to ensuring capability, keeping the industry in the U.S. provides economic and employment benefits, somewhat abating concerns over higher prices for U.S. built vessels. Thus, the team does not recommend *laissez-faire*. Based on discussions with personnel in Australia and consideration of the historical results achieved with government control of the “commanding heights,” the team does not recommend nationalization (one exception is that the U.S. should “nationalize” critical capabilities in danger of being lost, as the Portsmouth Navy Shipyard did for electric motor rewinding). Recommendations for each segment follow.

Defense

The primary recommendation for the defense segment is consolidation into two “super yards” for the construction of all naval vessels. To achieve this within ten years, officials should discuss the issue with industry representatives, and the USG should provide financial, contractual, and tax incentives to consolidate and reduce overhead and fixed costs. In addition, the government should oversee these efforts and all government support provided to the industry in order to ensure the best use of incentives to achieve desired results. The government should also consider consolidation of remaining U.S. Navy yards and maintenance facilities.

In order to address industry’s concern with the lack of a stable procurement plan, the U.S. Navy, DoD, and Congress must commit to improvement. As a start, the U.S. should fully fund the CNO’s 313-ship initiative, and the U.S. Navy, government, and industry should use it as a foundation on which to develop a long-term business plan. To address the issues of change orders and technology insertion, the USN and industry should continue to develop the interchangeable mission modules concept (see Essay 1) and increase research and development funding in order to provide more mature technologies during construction.

Commercial

Although not required for naval ship production or national security, a healthy commercial sector supports local economies, helps develop a supplier base, and sustains a skilled workforce. The team recommends that the USG provide targeted support, such as tax incentives and use of government real estate, and fully fund the Title XI loan guarantee program for ten years. The government should also encourage expanded demand and production by implementing the U. S. Maritime Administration’s short sea shipping initiative. This initiative involves changing the current tax structure, which discourages movement of cargo by sea, and establishing a national maritime system with multi-mode ports. If successful, this would create a new market for smaller vessels than those produced overseas. To support this, the U.S. should maintain the Jones Act for ten years to allow U.S. yards to become more competitive. In addition, the USG should not intervene if market forces cause further consolidation.

References

- Ahearn, D. (2006a, March 9). CNO's 313 ships plan would fix most operational limits of fleet. *Defense Today*.
- Ahearn, D. (2006b, January 12). 313-ship fleet may be unaffordable; cheaper options possible. *Defense Today*.
- Ahearn, D. (2006c, January 20). Etter sees new missions for littoral combat ships. *Defense Today*.
- American Shipbuilding Association. (2005). DoD releases annual report on China. Retrived May 24, 2006, from http://www.americanshipbuilding.com/show_newsarticle.cfm?id=67.
- Andrews, D. (2003, October 1). Re-engineering warship design and construction. *Jane's Navy International*.
- Associated Press (AP) (2006, February 8). Navy submits fleet expansion plan.
- Brown, N. & Scott R. (2003). Supporting cast enters the limelight. *Jane's Navy International* (November 1, 2003).
- Bruno, M. (2006, January 17). Foreign military naval sales possible with Navy's LCS. *Aerospace Daily & Defense Report*.
- Castelli, C. J. (2006, January 18). Navy shipbuilding plan called unrealistic. *InsideDefense News Stand*.
- Cavas, C. P. (2006a, February 8). 313-ship plan sent to congress. *Navy Times*.
- Cavas, C. P. (2006b, January 16). Mullen promises stable shipbuilding plan. *Defense News*.
- Cavas, C. P. (2006c, January 16). USN coastal ship attracts foreign interest. *Defense News*.
- Cebrowski, A. K. (2005, January 31). Alternate fleet architecture design. Office of the Secretary of Defense Report for the congressional Defense Committees.
- Conahan, F. (1990, April 26). *Status of the Navy's New Seawolf Attack Submarine and its new Combat System*. Testimony of the Assistant Comptroller General, National Security and International Affairs Division before the Legislation and National Security Subcommittee Committee on Government Operations, US House of Representatives. April 26, 1990. Retrieved on April 2, 2006, from <http://archive.gao.gov/d48t13/141247.pdf>
- Daniels, S. (2005). Alternative crewing strategies. *United States Naval Institute Proceedings*, 131(11), 77-78.
- Federation of American Scientists. (2006). *SSN 774 Virginia Class NSSN New Attack Submarine Centurion*. Retrieved April 2, 2006, from <http://www.fas.org/man/dod-101/sys/ship/nssn.htm>
- Fein, G. (2005a, November 10). LCS will require navy to examine future of small crews and modularity. *Defense Daily*.
- Fein, G. (2005b, November 19). Fewer sailors and declining budgets present unique challenges for Navy. *Defense Daily*.
- Fein, G. (2005c, July 27). LCS will be revolutionary change for Navy, ship's first commander says. *Defense Daily*.
- Fein, G. (2006a, February 23). Navy examining potential missions, including MIO, for littoral combat ship. *Defense Daily*.
- Fein, G. (2006b, February 24). Littoral combat ship's modularity – the shape of things to come for Navy. *Defense Daily*.
- First Marine International (FMI). (2005). *Global Shipbuilding Industrial Base Benchmarking Study - Part 1: Major Shipyards* (GSIBBS Part 1: Major Shipyards, p. 5). London: U.S.

- Department of Defense. Retrieved May 23, 2006, from http://www.acq.osd.mil/ip/docs/fmi_industry_report.pdf
- GovExec (2006, February 8). Navy sets shipbuilding goals requiring big funding boost. Retrieved from www.GovExec.com on February 15, 2006.
- IbisWorld. (2006). IbisWorld industry report: ship and boat building in the U.S. (February 6, 2006). IbisWorld, Inc.
- Konetzni, A. (2006, March 28). *Statement before the Projection Forces Subcommittee of the House Armed Services Committee*. March 28, 2006. Retrieved April 9, 2006, from <http://armedservices.house.gov/schedules/3-28-06KonetzniTestimony.pdf>
- Library of Congress (2006). *National Defense Authorization Act for Fiscal Year 1996. S.1124, Subtitle C, Section 131, Nuclear Attack Submarines*. Retrieved April 3, 2006, from <http://thomas.loc.gov/>.
- Montroll, M. L. (2002). Maintaining the technological lead. In H. Bennendijk (Ed.), *Transforming America's military* (pp. 345-369). Washington, DC: National Defense University Press.
- Krekich, A. (2006). Ship repair that supports the warfighter. *United States Naval Institute Proceedings*, 132(2) 24.
- Office of the Secretary of Defense (OSD). (2006). *Report to Congress on Annual Long-Range Plan for Construction of Naval Vessels for FY 2007*, Retrieved May 24, 2006, https://ucso1.hq.navy.mil/n7/webdoc01.nsf/lookup/068944AF88F8F48C85257110004D09C9/%24file/PB-%2B30%2BYR%2BSHIPBUILDING%2BPLAN_CNO_final.doc++Report+to+Congress+on+Annual+Long-Range+Plan+for+Construction+of+Naval+Vessels+for+FY+2007&hl=en&gl=us&ct=clnk&cd=1
- Office of the Secretary of Defense. (2006, February 6). *Quadrennial Defense Review Report*. February 6, 2006.
- O'Hanlon, M. E. (2005). *Defense strategies for the post-Saddam era*. Washington, D.C.: Brookings Institution Press.
- O'Rourke, R. (2006a, February 14). *Navy Attack Submarine Force-Level Goal and Procurement Rate: Background and Issues for Congress*, Congressional Research Services report RL32418. Retrieved March 27, 2006, from <http://navweb.secnaw.navy.mil/pubbud/04pres/highbook/04highlights.htm>.
- O'Rourke, R. (2006b, March 7). *Navy DD(X), CG(X), and LCS Ship Acquisition Programs: Oversight Issues and Option for Congress*, Congressional Research Service report RL32109.
- O'Rourke, R. (2006c, February 14). *Navy Force Structure and Shipbuilding Plan: Background and Issues for Congress*, Congressional Research Services report RL32665 Retrieved May 24, 2006, from http://digital.library.unt.edu/govdocs/crs//data/2006/upl-meta-crs-8466/RL32665_2006Feb14.pdf?PHPSESSID=c544c33af0388176a6713a0c33e68ac8.
- O'Rourke, Ronald. (2006d, March 15). *Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, before the House Armed Services Committee Subcommittee on Projection Forces, Hearing on Evolving Missions of the U.S. Navy and Surface and Subsurface Assets*.
- Porter, M. E. (1980). *Competitive strategy: techniques for analyzing industries and competitors*. New York: The Free Press.

- Rand Europe. (2005). *Differences Between Military and Commercial Shipbuilding: Implications for the United Kingdom's Ministry of Defence* (MG-236). Santa Monica, CA: Rand Corporation.
- Scott, R. (2004, July 1). Denmark's new standard ships offer great flex. *Jane's Navy International*.
- Scott, R. & Toremans, G. (2005, November 1). Danish fleet command organization. *Jane's Navy International*.
- Scutro, A. (2006, February 27). Full steam ahead: CNO's got big plans for the Navy. *Navy Times*.
- Simpson, J., Field, L. & Garvin, D. A. (1991). The Boeing 767: from concept to production, case study. Harvard Business School (HBS) case 9-688-040. Boston: Harvard Business School Publishing.
- Sirak, M. (2006, January 13). Navy shipbuilding plan doesn't float, analysts warn. *Defense Daily*.
- Submarine Warfare Division. (2006). *Key Themes: Force Structure*. Retrieved April 3, 2006, from <http://www.chinfo.navy.mil/navpalib/cno/n87/themes/forcestr.html>.
- Truver, S. C. (2003, September 1). LCS moves out of the shadows. *Jane's Navy International*.
- Truver, S. C. (2005a, March 1). Transformation: a bridge too far? *Jane's Navy International*.
- Truver, S. C. (2005b, March 16). Littoral combat ship – mix and match. *Jane's Navy Weekly*.
- USCG Maritime Strategy for Homeland Security (Coast Guard Publication 3-01). (December 2002). Washington, DC: The U.S. Coast Guard.
- U.S. Department of Commerce/Office of strategic industries and economic security (May 2001), National Security Assessment of the U.S. Shipbuilding and Repair Industry, [Technology assessment of the U.S. assistive technology industry, Appendix H] Retrieved May 24, 2006 from http://www.bis.doc.gov/DefenseIndustrialBasePrograms/OSIES/DefMarketResearchRpts/shi_building_and_repair.pdf.
- U.S. Department of the Navy. (2006, March 1). Statement of Admiral Michael G. Mullen, Chief of naval operations, before the House armed services committee, Hearing on military posture and FY 2007 budget.
- U.S. Department of Transportation. (2000). Shipyard Activity Reports data. In *Changing the Face of Transportation* (BTS00-007, pp. Figure 4-22). Washington, DC: U.S. Department of Transportation, Maritime Administration. Retrieved May 22, 2006, from http://www.bts.gov/publications/the_changing_face_of_transportation/html/figure_04_22.html.
- U.S., Government Accountability Office (GAO). (March 2005). *Defense acquisitions: assessments of selected major weapon programs*. Report to congressional committees (GAO-05-301). Washington, DC.
- United States General Accounting Office. (1994, October 20). *Navy Ships: Lessons of Prior Programs May Reduce New Attack Submarine Cost Increases and Delays*. Report Number NSIAD-95-4, dated 10/20/94. Retrieved April 2, 2006 from <http://www.fas.org/man/gao/gao954.htm>.
- United States General Accounting Office. (1995, January). *Navy's Aircraft Carrier Program, Investment Strategy and Options*. Report Number NSIAD-95-17, dated January 1995. Retrieved April 3, 2006 from <http://www.gao.gov/archive/1995/ns95017.pdf>.
- United States General Accounting Office. (1998, April 20). *New Attack Submarine: More Knowledge Needed to Understand Impact of Design Changes*. Report number NSIAD-98-

38, dated April 20, 1998. Retrieved April 3, 2006 from <http://www.fas.org/man/gao/nsiad98038.htm>.

Work, R. O. (2006, March 30). *Testimony before the House Armed Services Committee Projection Forces Subcommittee hearing on the Affordability of the Navy's 313-Ship Navy and the Executability of the 30-year Shipbuilding Plan*. Center for Strategic and Budgetary Assessments. Retrieved April 5, 2006, from <http://www.csbaonline.org/4Publications/Archive/T.20060330.FleetTestimony/T.20060330.FleetTestimony.pdf>.

Wrightson, M. T. (2005, June 21). U.S. Government Accountability Office (GAO). *Preliminary observations on the condition of deepwater legacy assets and acquisition management challenges*. Testimony before the subcommittee on fisheries and the Coast Guard, Committee on Commerce, Science, and Transportation, U.S. Senate (GAO-05-651).

Zimmerman, J., & Bissell, J. (2005). Global shipbuilding industrial base benchmarking study part I: major shipyards, *Office of the Deputy Under Secretary of Defense (Industrial Policy)*, May 2005. Retrieved April 3, 2006, from <http://www.acq.osd.mil/ip>.

